## (D) Remarks

***Specification***

In paragraph 5 of the office action, correction of lines 20-21 of page 23 is requested. It is respectfully submitted that the present sentence is actually correct. The hats on top of a variable refer to variables that have been transformed into the Fourier domain as per Equation (4) line 25 of page 23. Lines 20 and 21 refer to those variables, not to the transformed variables.

***Claim rejections – 35 USC §112***

- **Equation (1) and (2)**

In Equation (1) and (2) the index notation was used. In this standard notation, a repeated literal index in any term of an expression implies summation.

For example, $\sigma_{ij,j}$ means

$\sigma_{ij,j} = \sigma_{i1,1} + \sigma_{i2,2} + \sigma_{i3,3}$ (Line 7 of page 22, it is noted that a 3-D body is assumed, therefore the ranges of i and j are 1 to 3).

The comma preceding an index denotes partial differentiation with respect to that variable represented by that index.; $u_{i,j}$ thus denotes $\partial u_i / \partial x_j$. The notation used in Equation (1) is consequently a shortcut for describing the following equations:

$$\frac{\partial \sigma_{xx}}{\partial x} + \frac{\partial \sigma_{xy}}{\partial y} + \frac{\partial \sigma_{xz}}{\partial z} + b_x = 0$$

$$\frac{\partial \sigma_{yx}}{\partial x} + \frac{\partial \sigma_{yy}}{\partial y} + \frac{\partial \sigma_{yz}}{\partial z} + b_y = 0$$

$$\frac{\partial \sigma_{zx}}{\partial x} + \frac{\partial \sigma_{zy}}{\partial y} + \frac{\partial \sigma_{zz}}{\partial z} + b_z = 0$$

Details about the index notation can be found for instance in " Boundary Element Methods In Solid Mechanic, by S.L. Crouch and A.M. Starfield, first published in 1983, with copies of pages 8-9 and 17-18 attached to this response.

- **Roots $\alpha_j$ page 25, lines 4-6**

As noted by the Examiner, the roots alpha are layer dependent as well as other variables and as noted in equation (12). Appropriate correction of pages 24 and 25 (Equations (6), (7) and (8) where $\alpha_j$ is replaced by $\alpha_j^l$ is therefore proposed.

- **Term $b_j$ page 25, lines 6-8**

In equation (1), the choice of index is irrelevant since the variable in not embedded in an equation. Therefore, the term $b_i$ in equation (1) can be indifferently re-written $b_j$ (it always implies $b_1$, $b_2$ and $b_3$)

- **Lines 6-7, page 7**

The phrase "at least one of the following" has been removed.

- **Claim 8**

In claim 8, the term "in real-time" has been removed from paragraph (h).

- **Claim 3**

In claim 3, the term "in some cases" has been removed from lines 1-2.

- **Claim 11**

Claim 11 has been deleted.

***<u>Claim rejections – 35 USC §102</u>***

Claims 1, 2, 5 and 20 as filed were rejected under 35 USC §102 in view of GOHFER. Claims 5 and 20 have been deleted. Claim 1 (and consequently claim 2 depending on claim 1) has been amended to recite that the data relate to layered reservoirs and that the equilibrium equations are solved for each layerby the use of a

Fourier Transform method. Therefore claim 1 as revised is not anticipated by GOHFER that does not use a Fourier Transform method.

***Claim rejections – 35 USC §103***

Claims 13-19 were rejected under 35 USC §103 as being unpatentable over GOHFER in view of Linkov. However, as explained by Eduard Siebrits in the sworn declaration attached to this response, the author of the GOHFER model has always stated that his model was applicable to multi-layered formations and therefore one skilled in the art of modeling fracturing treatment had no reason to modify that model to add a function that was arguably already included. Moreover, Mr. Siebrits further declares that according to their authors, the Linkov model was not applicable for the case of cavities or cracks intersecting the layers boundaries as it is the case with hydraulic fracturing. Therefore it was not obvious for one skilled in the art to combine the teaching of the Linkov model to the GOHFER model for providing a new and improved model of hydraulic fracturing.

Applicants submit that this response addresses all of the issues raised in the official action respectfully request reconsideration and that a timely Notice of Allowance be issued in this case.

It is believed fees are due for this reply. Should additional fees or refunds be due, the Commissioner is authorized to charge or credit any necessary fee to Deposit Account No. 04-1579(56.0428).

Respectfully submitted,

Catherine MENES
Limited Recognition
Agent for Applicants

Date: June 25, 2003

Schlumberger Technology Corporation
110 Schlumberger Drive, MD1
Sugar Land, Texas 77478
(281) 285-8606
FAX: (281) 285-8569

A method and device is disclosed in which the device comprises a means for storing instructions, said instructions adapted to be executed by a processor of a computer. Further, the instructions when executed by the processor should be capable of executing a process comprising the steps of obtaining a first data set, the first data set comprising ~~at least one of the following~~: time history of fluid volumes, time history of proppant volumes, fluid properties, proppant properties, and geological properties. Additionally, the method includes a means for providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships. A further step relates to computing by said processor a first set of values by manipulating said first data set using said stored equations. It is possible then to determine from said first set of values dimensions of a hydraulic fracture, the dimensions including fracture height and length, fracture width, and fluid pressures as a function of time. In a further embodiment, the step of converting said first set of values into a set of output

$$L\left(C_{ijkl}\right)\begin{bmatrix}\hat{u}_x\\ \hat{u}_y\\ \hat{u}_z\end{bmatrix}=\begin{bmatrix}\hat{b}_x\\ \hat{b}_y\\ \hat{b}_z\end{bmatrix} \tag{5}$$

For a layered material, there is a system of differential equations of the form (5) for each layer, each of whose coefficients are determined by the material properties of the layer. It is possible to solve the system of differential equations for a typical layer $l$ to obtain the general solution to the $r$ th displacement components in the form:

$$\hat{u}_r^l=\sum_j d_{jr}^l e^{\alpha_j^l kz} A_j^l(k) \tag{6}$$

where $k=\sqrt{m^2+n^2}$

In the case of repeated roots of the characteristic equation associated with (5), which occurs for the important case of isotropic layers, the system (5) has the general solution:

$$\hat{u}^l_r = \sum_j \left(d^l_{jr} + f^l_{jr} z\right) e^{\alpha^l_j kz} A^l_j(k) \tag{7}$$

Here $d^l_{jr}$ and $f^l_{jr}$ are constants that depend on the material constants of the layer, the $\alpha^l_i$ are the roots of the characteristic equation for the system of ordinary differential equations, and the $A^l_j(k)$ are free parameters of the solution that are determined by the forcing terms $b_j$ in (1) and the interface conditions prescribed at the boundary between each of the layers (e.g. bonded, frictionless, etc.).

Substituting these displacement components into the stress strain law (2), we can obtain the corresponding stress components: $\hat{\sigma}_{XX}$, $\hat{\sigma}_{yy}$, $\hat{\sigma}_{zz}$, $\hat{\sigma}_{xy}$, $\hat{\sigma}_{xz}$, and $\hat{\sigma}_{yz}$, which can be expressed in the form:

$$\hat{\sigma}^l_{pq} = \sum_j \left(s^l_{jpq}\right) e^{\alpha^l_j kz} A^l_j(k) \tag{8}$$

In the case of repeated roots the stress components assume the form:

1. (Currently Amended) A device comprising means for storing instructions, said instructions adapted to be executed by a processor of a computer, said instructions when executed by the processor executing a process comprising the steps of

(a) obtaining a first data set, the first data set comprising at least one of the following:

time history of fluid volumes,
time history of proppant volumes,
fluid properties,
proppant properties, and
geological properties of a layered reservoir, including layer interface locations,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations, said manipulation including solving the equilibrium equations for each layers by the use of a Fourier Transform method whereby the relations between stress and strain in the layered reservoir are determined,

(d) determining from said first set of values dimensions of a hydraulic fracture, the dimensions including fracture height and length, fracture width and fluid pressures as a function of time, said hydraulic fracture intersecting at least one layer interface,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time,

(f) displaying the output data on a computer monitor.

2. The device of claim 1 further wherein the step of determining from said first set of values dimensions of a hydraulic fracture is achieved using a mesh of elements.

3. (Currently Amended) The device of claim 1 wherein the elements may ~~in some cases~~ be only partially active.

4. The device of claim 2 further wherein during the determining step recalculation of fully active elements is not required during determination of said first set of values.

5. (Canceled).

6. A device comprising means for storing instructions, said instructions adapted to be executed by a processor of a computer, said instructions when executed by the processor executing a process comprising the steps of

(a) obtaining a first data set, the first data set comprising one or more of the following:

time history of fluid volumes for pumping,

time history of proppant volumes for pumping,

fluid properties,

proppant properties, and

logs of geological information,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations,

(d) determining from said first set of values the dimensions of a hydraulic fracture using a mesh of elements, said dimensions including fracture height and length, fracture width and fluid pressures as a function of time, wherein the elements are capable of being only partially active, further wherein the recalculation of fully active elements is not required during determination of said first set of values,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time,

(f) displaying, transmitting, or printing the output data.

7. A method of designing a hydraulic fracture of a well, comprising:

(a) obtaining a first data set, the first data set comprising one or more of the following:

time history of fluid volumes for pumping,

time history of proppant volumes for pumping,

fluid properties,

proppant properties, and

logs,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations,

(d) determining from said first set of values the dimensions of a hydraulic fracture using a mesh of elements, said dimensions including fracture height and length, fracture width and fluid pressures as a function of time, wherein the elements are capable of being only partially active, further wherein the recalculation of fully active elements is not required during determination of said first set of values,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time,

(f) displaying the output data.

8. (Currently Amended) A method for monitoring or evaluating the fracture of a well in real time, comprising:

(a) pumping a fracturing fluid into a wellbore,

(b) obtaining a first data set, the first data set comprising one or more of the following:

time history of fluid volumes for pumping,

time history of proppant volumes for pumping,

fluid properties,

proppant properties, and

logs,

(c) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(d) computing by said processor a first set of values by manipulating said first data set using said stored equations,

(e) determining from said first set of values the dimensions of a hydraulic fracture using a mesh of elements, said dimensions including fracture dimensions and fluid pressures as a function of time, wherein the elements are capable of being only partially active, further wherein the recalculation of fully active elements is not required during determination of said first set of values,

(f) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time,

(g) displaying the output data, and

(h) monitoring the pumping step (a) to determine fracturing performance ~~in real time~~.

9. A method of evaluating the fracture of a well following a fracturing operation, comprising:

(a) fracturing a well,

(b) obtaining a first data set, the first data set comprising one or more of the following data points obtained during step (a):

time history of fluid volumes for pumping,

time history of proppant volumes for pumping,

fluid properties,

proppant properties, and

logs,

(c) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(d) computing by said processor a first set of values by manipulating said first data set using said stored equations,

(e) determining from said first set of values the dimensions of a hydraulic fracture using a mesh of elements, said dimensions including fracture dimensions and fluid pressures as a function of time, wherein the elements are capable of being only partially active, further wherein the recalculation of fully active elements is not required during determination of said first set of values,

(f) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time,

(g) displaying the output data.

10. An article of manufacture, comprising:

(a) magnetic storage means having encoded thereon instructions,

(b) a computer, the computer having a processor, wherein the processor is operably connected to said magnetic storage means,

(c) wherein data is provided representing the time history of fluid volumes, fluid properties, and proppant properties required to fracture a reservoir of a reservoir,

(d) the processor being adapted to calculate values that correlate to said data, the values representing physical properties related to the reservoir or well fracturing operations using fluids, the values being used to estimate fracturing fluid performance,

(e) the processor being capable of processing such data using numerical methods that subdivide a fracture numerical mesh into elements for purposes of calculation, said

elements being generally capable of adopting a status as fully active, partially active, or inactive for calculation purposes, further wherein recalculation of fully active elements is not required.

11. (Canceled).

12. A system adapted to process data to optimize the placement of a fracture in a subterranean formation, comprising:

(a) obtaining a first data set, the first data set comprising one or more of the following:

time history of fluid volumes for pumping,

time history of proppant volumes for pumping,

fluid properties,

proppant properties, and

logs identifying geological zones in a reservoir,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations,

(d) determining from said first set of values the dimensions of a hydraulic fracture using a mesh of elements, said dimensions including fracture dimensions and fluid pressures as a function of time, wherein the elements are capable of being only partially active, further wherein the recalculation of fully active elements is not required during determination of said first set of values,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time, and

(f) displaying the output data.

13. (Amended) A method comprising:

(a) obtaining a first data set,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having electronic storage means with stored equations comprising hydraulic fracturing relationships, the relationships comprising a Fourier Transform solution of multilayer equilibrium equations, the solution employing at least one inversion process,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations, the equations including a Green's function or influence matrix,

(d) determining the dimensions of a hydraulic fracture <u>intersecting several layers</u> using a mesh of elements,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time.

14. The method of claim 13 further comprising the step of: (f) displaying the data for a user.

15. The method of claim 13 further comprising the step of: (f) sending the data to a remote site by way of a transmission medium.

16. The method of claim 13 further comprising the step of: (f) printing the output data.

17. (Currently Amended) A device comprising a pre-recorded means readable by a computer and carrying instructions for a process, the instructions comprising the steps of:

(a) obtaining a first data set,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having pre-recorded means with stored equations comprising hydraulic fracturing relationships, the relationships comprising a Fourier Transform solution of multilayer equilibrium equations, the solution employing at least one inversion process,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations, the equations including a Green's function or influence matrix,

(d) determining the dimensions of a hydraulic fracture intersecting several layers using a mesh of elements, and

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time.

18. The device of claim 17, wherein said pre-recorded means is selected from the group of magnetic tape, a magnetic disk, an optical disk, a CD-ROM.

19. (Currently Amended) A report generated by illustrating a characteristic or set of values for a fracturing operation of a formation penetrated by a wellbore, said formation having a reservoir of oil or gas, comprising the steps of:

(a) obtaining a first data set,

(b) providing the first data set to a computer, the computer having a processor capable of executing instructions, the computer further having pre-recorded means with stored equations comprising hydraulic fracturing relationships, the relationships comprising a Fourier Transform solution of multilayer equilibrium equations, the solution employing at least one inversion process,

(c) computing by said processor a first set of values by manipulating said first data set using said stored equations, the equations including a Green's function or influence matrix,

(d) determining the dimensions of a hydraulic fracture intersecting several layers using a mesh of elements,

(e) converting said first set of values into a set of output data, the output data representing fracture dimensions and pressures as a function of pumping time, and

(f) generating a report.

20 (Canceled).